

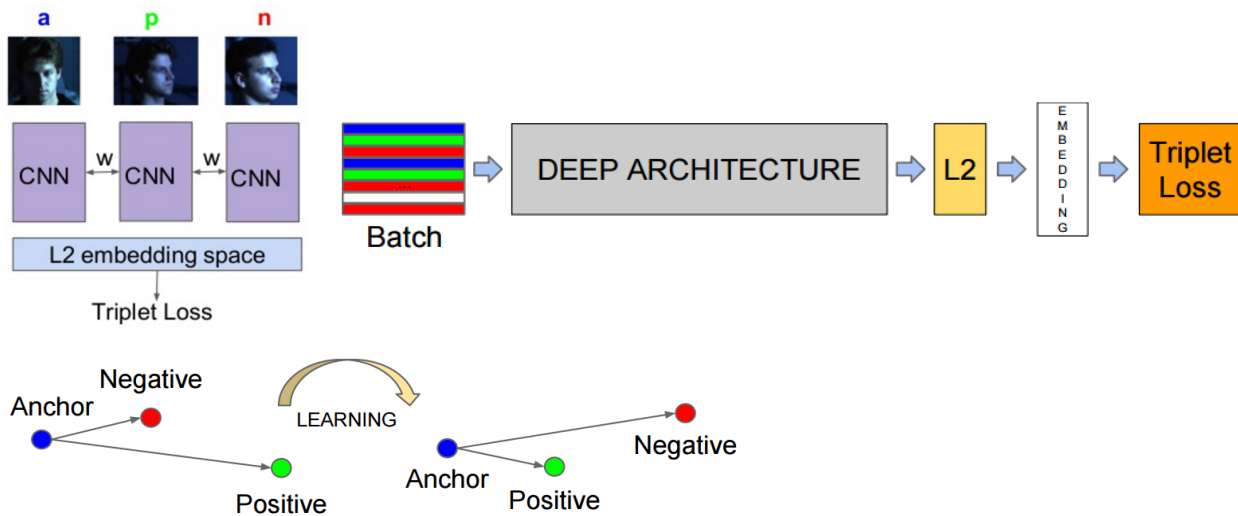
Triplet Loss

Introduction

The triplet loss is often used on person re-identification or face recognition problems, the idea of triplet loss is to receive 3 scores, 1 anchor score, a related positive score and an extra negative score related to a "negative class". The training objective will minimize this loss by making related scores similar while making the difference between the anchor scores and the negative score larger.

$$Loss_{triplet} = \sum_{i=1}^N \left[L_{2distance}(f_{anchor}[i] - f_{positive}[i])^2 - L_{2distance}(f_{anchor}[i] - f_{negative}[i])^2 + \alpha \right]_+$$

The triplet loss has 3 inputs, which are the output of a neural network, a class called "anchor class", another class that is positive, and a negative class. On a face recognition problem the anchor class could be a person, and positive class could be the same person under other illumination, and a negative class a different person.

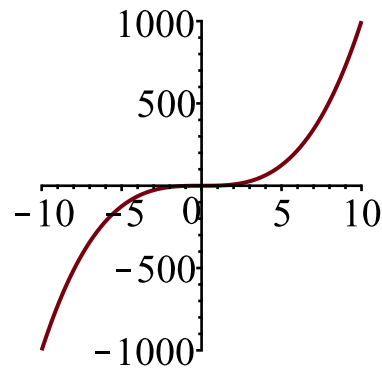


Sometimes the inputs of the triplet loss comes from 3 different networks that share the same weights, but this also can be achieved by using a single network and building the batch with the anchor, positive and negative class. This also implies that if the triplet loss has 3 inputs during backpropagation we should return 3 gradients.

Hinge effect

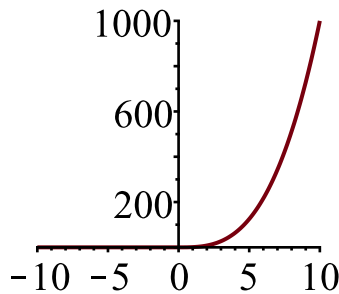
Notice at the end of the Triplet loss function the "+" sign, this indicate that the loss that the function will not have negative values. This is done to avoid having a negative loss, and giving a loss of zero on the case that the distance (Anchor...negative + alpha) is bigger than (Anchor...Positive). This also will have effects on it's gradients. To illustrate better this process I will define some simple functions with this behaviour.

$$\text{someFunc} := x \rightarrow x^3 = x \rightarrow x^3 \rightarrow$$



Now if we want that this function output only positive values we could say

$$\text{someFunc}_{\max} := (x) \rightarrow \max(0, \text{someFunc}(x)) = x \rightarrow \max(0, \text{someFunc}(x)) \rightarrow$$



This also implies that the gradient of this functions would be different

$$\frac{d}{dx} \text{someFunc}(x) = 3x^2$$

$$\frac{d}{dx} \text{someFunc}_{\max}(x) = \begin{cases} 0 & x \leq 0 \\ 3x^2 & 0 < x \end{cases}$$

Euclidian distance (Or L2 distance)

Like other distances (ie L1 distance) the L2 distance return a scalar that represent how 2 vectors(p,q) are similar to each other.

$$p := [1, 2, 3] = [1, 2, 3]$$

$$q := [1.1, 2, 3.3] = [1.1, 2, 3.3]$$

$$L_2 := (a, b, N) \rightarrow \sqrt{\sum_{i=1}^N (a[i] - b[i])^2} = (a, b, N) \rightarrow \sqrt{\sum_{i=1}^N (a_i - b_i)^2}$$

$$L_2(p, q, 3) = 0.3162277660$$

$$L_2(p_v, q_v, 3) = \sqrt{(p_{v_1} - q_{v_1})^2 + (p_{v_2} - q_{v_2})^2 + (p_{v_3} - q_{v_3})^2}$$

On the context of loss functions we use the square l2 distance to actually cancel the squar-root term.

$$\|p_i - q_i\|_2^2 = \left(\sqrt{\sum_{i=1}^N (a[i] - b[i])^2} \right)^2$$

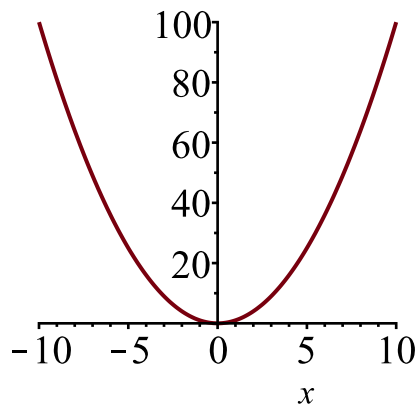
This sometimes causes confusion because now it will be called L2-norm loss

$$L_{2_{loss}} := (a, b, N) \rightarrow \sum_{i=1}^N (a[i] - b[i])^2 = (a, b, N) \rightarrow \sum_{i=1}^N (a_i - b_i)^2$$

$$L_{2_{loss}}(p, q, 3) = 0.10$$

$$L_{2_{loss}}(p_v, q_v, 3) = (p_{v_1} - q_{v_1})^2 + (p_{v_2} - q_{v_2})^2 + (p_{v_3} - q_{v_3})^2$$

Also for illustration purposes this is how the plot of the L2-norm loss looks like $L_{2_{loss_{plot}}} := x^2 = x^2 \rightarrow$



There is a variant of the L2-norm loss called MSE (Mean squared error) loss which divide the L2-norm loss by the batch-size, the idea is to decouple the batch size from the loss value.

$$MSE_{loss} := (a, b, N) \rightarrow \frac{1}{N} \cdot \left(\sum_{i=1}^N (a[i] - b[i])^2 \right) = (a, b, N) \rightarrow \frac{\sum_{i=1}^N (a_i - b_i)^2}{N}$$

$$MSE_{loss}(p_v, q_v, 3) = \frac{1}{3} (p_{v_1} - q_{v_1})^2 + \frac{1}{3} (p_{v_2} - q_{v_2})^2 + \frac{1}{3} (p_{v_3} - q_{v_3})^2$$

Get the derivative of L2-norm loss w.r.t to input

Before we delve into the gradient of the triplet-loss let's investigate how to find the derivative of the L2-norm function, by definition the idea of the norm function is to give a positive scalar number that represent the size of a vector, so we can consider the following simplification.

$$\sum_{i=1}^N (a[i] - b[i])^2 \Rightarrow \sum_{i=1}^N u^2, \text{ where } u \text{ will be a function that calculate the difference } (a[i] - b[i]) \text{ vector}$$

Let's just lay out some derivatives rules, consider u as a function

Scalar multiple rule: $\frac{d}{dx} (\alpha \cdot u) = \alpha \frac{d}{dx} u$

Sum Rule: $\frac{d}{dx} \sum u = \sum \frac{d}{dx} u$, this is nice because I don't know yet how to calculate derivatives with sum properly on maple

$$\text{sum} \cdot \frac{\partial}{\partial a} (a - b)^2 = \text{sum} (2 a - 2 b)$$

$$\text{sum} \cdot \frac{\partial}{\partial b} (a - b)^2 = \text{sum} (-2 a + 2 b)$$

Putting all together

Now let's put together the L2-norm inside the triplet loss, and also push outside all the \sum operators

$$f := (\text{anchor}, \text{positive}, \text{negative}, \alpha) \rightarrow [(\text{anchor} - \text{positive})^2 - (\text{anchor} - \text{negative})^2 + \alpha] =$$

$$(\text{anchor}, \text{positive}, \text{negative}, \alpha) \rightarrow [(\text{anchor} - \text{positive})^2 - (\text{anchor} - \text{negative})^2 + \alpha]$$

$$\frac{d}{d \text{ anchor}} f(\text{anchor}, \text{positive}, \text{negative}, \alpha) = [-2 \text{ positive} + 2 \text{ negative}]$$

$$\frac{d}{d \text{ positive}} f(\text{anchor}, \text{positive}, \text{negative}, \alpha) = [-2 \text{ anchor} + 2 \text{ positive}]$$

$$\frac{d}{d \text{ negative}} f(\text{anchor}, \text{positive}, \text{negative}, \alpha) = [2 \text{ anchor} - 2 \text{ negative}]$$

Now I just isolate the factors from the expression:

$$\text{factors}(-2 \text{ positive} + 2 \text{ negative}) = [2, [[\text{negative} - \text{positive}, 1]]]$$

$$\text{factors}(-2 \text{ anchor} + 2 \text{ positive}) = [-2, [[\text{anchor} - \text{positive}, 1]]]$$

$$\text{factors}(2 \text{ anchor} - 2 \text{ negative}) = [2, [[\text{anchor} - \text{negative}, 1]]]$$

Gradients of Triplet loss

Due to the fact that the triplet loss wants to make the distance between $[f_{\text{anchor}}, f_{\text{positive}}]$ small while making the distance $[f_{\text{anchor}}, f_{\text{negative}}]$ big by an α factor the gradients will be zero if the expression:

$$[L_{2\text{distance}}(f_{\text{anchor}} - f_{\text{positive}})^2 - L_{2\text{distance}}(f_{\text{anchor}} - f_{\text{negative}})^2 + \alpha]$$

gives a negative number (≤ 0), because it would imply that $[L_{2\text{distance}}(f_{\text{anchor}} - f_{\text{positive}})^2]$ is already bigger than $[L_{2\text{distance}}(f_{\text{anchor}} - f_{\text{negative}})^2 + \alpha]$

Gradient w.r.t anchor input

$$\frac{\partial}{\partial f_{\text{anchor}}} \text{Loss}_{\text{triplet}} = \sum_{i=1}^N [2(f_{\text{negative}} - f_{\text{positive}})]$$

Gradient w.r.t positive input

$$\frac{\partial}{\partial f_{\text{positive}}} \text{Loss}_{\text{triplet}} = \sum_{i=1}^N [-2(f_{\text{anchor}} - f_{\text{positive}})]$$

Gradient w.r.t negative input

$$\frac{\partial}{\partial f_{\text{negative}}} \text{Loss}_{\text{triplet}} = \sum_{i=1}^N [2(f_{\text{anchor}} - f_{\text{negative}})]$$

References

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